BBC RD 1976/1

1969 1974
THE QUEEN'S AWARD TO INDUSTRY

BBC

RESEARCH DEPARTMENT

REPORT

DIGITAL VIDEO RECORDING: some experiments in error protection

C.D. Mathers, M.Sc.

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION January 1976

BBC RD 1976/1
UDC 621.397.3

DIGITAL VIDEO RECORDING:
SOME EXPERIMENTS IN ERROR PROTECTION

C.D. Mathers, M.Sc.

Summary

This report describes two error-protection systems which were designed for use with the experimental digital television recorder. These systems were developed as part of a more general investigation into error protection for digital television recording. In the first, concealment of error bursts is controlled by a detection system based on parity bits which constitute 4·8% of the total data rate. In the second system the least significant data bit is sacrificed to make 16·7% of the data capacity available for parity bits; this permits correction of error bursts and concealment of isolated errors.

It is concluded that, using the techniques described, acceptable pictures are obtainable with a small ratio of parity bits to data bits, but that a higher ratio than is at present available would be required to prevent perceptible loss of picture quality in multiple-generation recordings.

Issued under the authority of

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

January 1976

(PH-149)

DIGITAL VIDEO RECORDING:
SOME EXPERIMENTS IN ERROR PROTECTION

Section Title Page

Summary .... Title Page

1. Introduction 1

2. Concealment and correction of errors in digitised video signals 1

3. Errors in digital magnetic recording 1

4. System 1: error concealment 1

   4.1. Parity allocation scheme 1
   4.2. Method of instrumentation 2

5. System 2: error correction and concealment 2

   5.1. Parity allocation scheme 2
   5.2. Method of instrumentation 3

6. Results 5

7. Conclusions 5

8. References 7

DIGITAL VIDEO RECORDING: SOME EXPERIMENTS IN ERROR PROTECTION

C.D. Mathers, M.Sc.

1. Introduction

The recording of data at high densities on magnetic tape is subject to errors which cannot in general be neglected; data recorders therefore usually include some form of error protection system. The recent development of an experimental digital video recorder[1] provided an opportunity to perform some experiments in the field of error protection. Two pieces of equipment were constructed and tested; although their design is specific to the television recorder, the principles involved and the results obtained are of more general interest. The first (System 1) operates on 8-bit video samples and uses a well-known error concealment technique; in the second (System 2) the least significant bit of the data is replaced by a parity bit which provides sufficient additional information for more reliable concealment as well as a significant degree of error correction.*

2. Concealment and correction of errors in digitised video signals

If one of the bits of an 8-bit digitised PAL-encoded video signal is known to be in error, the subjective impairment which would result may in some cases be considerably reduced if the affected sample is replaced by an estimate based on nearby picture information.[2] In a monochrome picture the erroneous sample may be replaced by the preceding one, or by the average of the previous and subsequent samples. (Higher orders of interpolation may clearly be used, but the additional improvement is likely to be small.) In a colour picture, it is desirable that the colour-subcarrier component of the erroneous sample should be preserved with reasonable accuracy. This is most likely to be achieved if the substitute information is derived from nearby points in the picture which are separated from the erroneous sample by a whole number of subcarrier cycles. If the video signal has been sampled at n times subcarrier frequency, the substitute information may be, for example, the nth previous sample, or the average of the nth previous and nth subsequent samples.

The residual subjective impairment caused by this latter form of error concealment approximates to that caused by unconcealed errors in the 4th significant bit; the technique is therefore applicable only to errors in the 4 most significant bits.

Error concealment requires only that the word in error be located, whereas for correction it is also necessary to identify the erroneous bit or bits contained in the word. Occasional mistaken application of the concealment technique causes negligible picture impairment, whereas a mistaken attempt to correct one or more of the bits causes errors of the precise nature that an error protection system is designed to avoid. For this reason, concealment may be used when an error is suspected, but correction may be applied only when an error is identified beyond reasonable doubt.

3. Errors in digital magnetic recording

Errors in high-density multitrack longitudinal recordings are caused mainly by tape dropouts. These result from small imperfections in the oxide coating, or momentary separations between head and tape due to dust or free particles of oxide. Dropouts appear to affect at most about 30 mils. of track length, corresponding to a loss of about 1000 bits; a single dropout rarely affects more than one track.

The average error rate of the television recorder involved in the experiments is about 10^{-5}; the probability of errors occurring simultaneously on two or more tracks is therefore very small. In the design of error protection systems, advantage can be taken of two properties of this form of error distribution:

(i) Single isolated errors are relatively rare: the majority occur in bursts of appreciable length.

(ii) Errors rarely occur on more than one track at a time.

It was initially assumed that, during a tape dropout, a random string of ones and zeros would be produced from the resultant noise after amplitude limiting in the data regeneration circuits, but for two reasons this is not true for the machine in question. First, the data is recorded using delay modulation; for instrumental reasons the delay-modulation decoder used is twice as likely to produce a one as a zero when fed with clipped noise. Secondly, due to assymmetries in the off-tape waveforms, optimum data regeneration is usually obtained with the clipper set sufficiently far off-centre to be unaffected by noise; in this case the decoder output remains continuously at 0 or 1 during a dropout.

A tape dropout may thus produce occasional strings of fortuitously correct data rather than a continuous 50% error rate; this reduces the effective number of errors, but can make the location of the dropout more difficult.

4. System 1: error concealment

4.1. Parity allocation scheme

The recording format of the machine is shown diagrammatically in Fig. 1. Groups of five 8-bit words are

---

* The principles on which both systems are based are due to A.H. Jones.

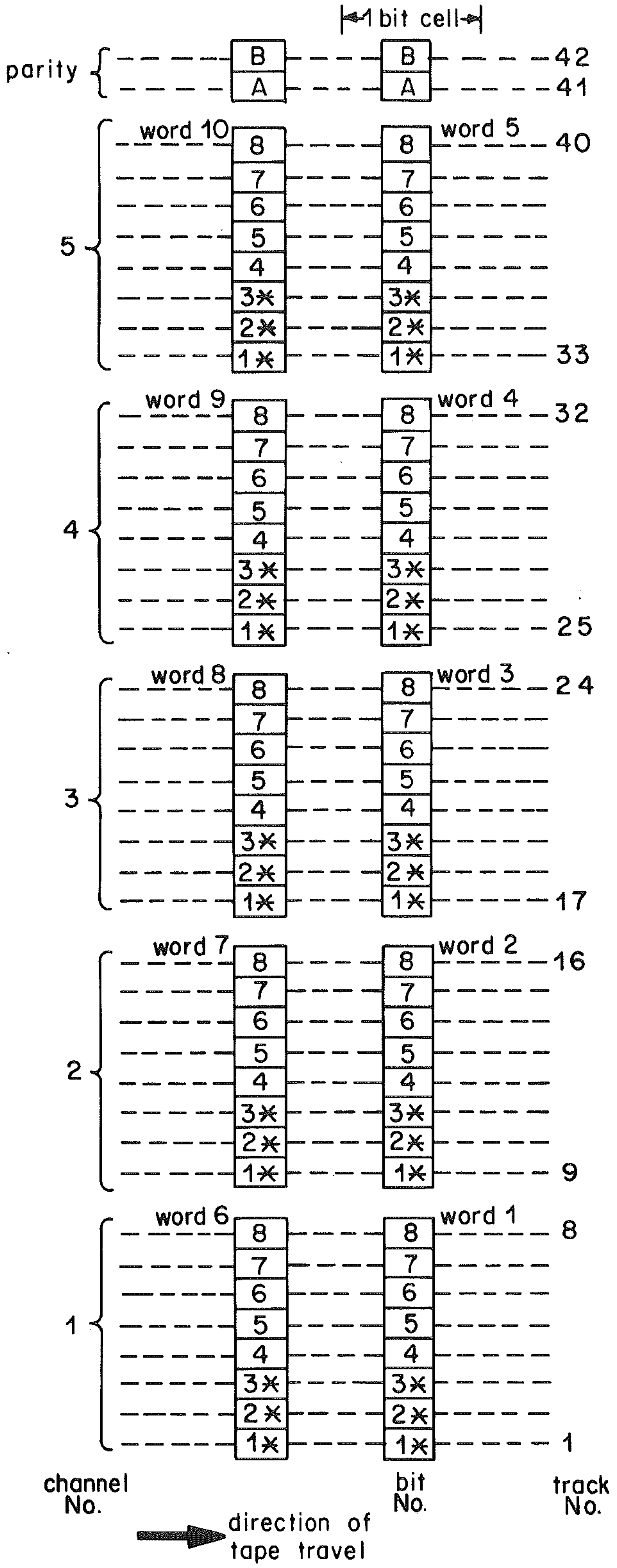


Fig. 1 - Recording format of digital television recorder

recorded on 40 of the 42 parallel tracks so that the bit rate per track is one-fifth of the video word rate. The two remaining tracks carry parity bits; a cross-section of the tape therefore carries five 8-bit words plus two parity bits.

As stated previously, a data error can be concealed if the word in which it has occurred is known. Two parity bits are clearly insufficient to indicate in which of 5 words a single isolated error is located, but a burst of errors which is confined to one eight-track channel and which is of sufficient duration can be located by ascribing the parity bits to the channels in a cyclic order, and then identifying the resultant pattern of parity-check failures. The parity allocation cycle chosen is given in Table 1 which also shows the parity indication pattern resulting from continuous errors in one of the channels.

The probability that an error burst will be located depends on the error distribution and on the number of parity cycles that are available for examination. Table 2 lists some calculated values of this probability for various number of parity cycles, based on the simplifying assumption that the average error rate during the burst is always 50%, i.e. that the spurious data produced during the error burst is purely random.

Because of the limitations of the error concealment method, only the three most significant bits of each word are protected by parity; this means that 15 tracks in all are included in the protection scheme (Fig. 1).

4.2. Method of instrumentation

The principle of operation of the parity generator is illustrated in Fig. 2(*a*). One pair of parity bits A, B is generated for every 5 video words in accordance with Table 1; these are clocked out at frequency f/5 where f denotes the word rate. The f/6 square wave switches consecutive groups of three input words alternately between parity accumulators A and B; a 30-word parity cycle therefore includes all phases of f/6 relative to f/5.

On the replay side of the recorder (Fig. 2(*b*)), parity bits are again generated from the data, and checked against the recorded parity bits. The replayed data provides no direct indication of when a parity cycle begins; there are 6 possibilities corresponding to the 6 relative phases of f/6 and f/5. By comparing the outputs of 6 differently phased parity generators with the recorded parity, the appropriate phase of f/6 may be chosen with negligible probability of error, even during sustained error bursts.

Parity-check failures are accumulated until one of the 5 possible patterns is recognised; in the meantime the video data is delayed by a buffer store. When the location of an error burst is established, error concealment is applied to data from the affected channel each time parity failure occurs; for this purpose the parity checks must be delayed by the same amount as the data. The optimum size of buffer store is not critical; in the investigation the amount of storage used (512 words) was determined by the most readily available length of shift register.

5. System 2: error correction and concealment

5.1. Parity allocation scheme

In this system, the least significant (8th) bit of each word is replaced (at the expense of some loss in signal

TABLE 1

Parity Allocation Scheme for System 1: One Complete Parity Cycle
As an example, the parity check output is also shown for continuous errors in Channel 4

WORD NO. →		1 2 3 4 5	10	15	20	25	30	
protected by PARITY BIT →		A A B B B	A A A B B	B A A A B	B B A A A	B B B A A	A B B B A	etc.
PARITY CHECK (NO ERRORS)	A→	0	0	0	0	0	0	
	B→	0	0	0	0	0	0	
PARITY CHECK (CONTINUOUS ERRORS IN CHANNEL 4)	A→	0	0	1	1	1	0	
	B→	1	1	0	0	0	1	

TABLE 2

Probability of Error-Burst Location as a Function of the Number of Parity Cycles Examined (50% Error Rate is Assumed During Burst)

No. of Parity Cycles Examined	Probability of Error-Channel Location	Probability of Error-Channel Non-Location
1	0·5625	1 in 2·3
2	0·8086	1 in 5·2
3	0·9163	1 in 12·0
4	0·9634	1 in 27
5	0·9840	1 in 63
6	0·9930	1 in 143
7	0·9969	1 in 326
8	0·9987	1 in 746
17	(This corresponds to storage used in prototype)	1 in $1{\cdot}27 \times 10^6$

quality) by a parity bit, designated W. Provided that two or more errors do not occur in the same word, bit W provides sufficient information to permit concealment of all data errors.

The parity tracks A and B which, as in System 1, carry two parity bits for every 5 words, can now be employed in determining the significance of data bits affected by an error burst. This information is complementary to that provided by parity bit W; by using A, B and W, sufficient information can usually be obtained to enable sustained error bursts to be corrected. Isolated errors or very short bursts are located by W only, and may be concealed.

The allocation scheme chosen for parity bits A and B is shown in Fig. 3. Only the 4 most significant bits of the data are protected. By using A to protect bits 1 and 4 alternately, and B similarly for bits 2 and 3, the parity bits A and B are given approximately equal weight. Each parity bit W represents the modulo 2 sum of the 4 most significant bits of one word. Thus, for example, an error in bit 4 of word 1 would be detected by W, but would be missed by A and B. If, however, the error were repeated in bit 4 of word 6, it would be detected by both W and A. W would indicate that the error was in word 6, and A that it affected bit 4; by inverting this bit the error may therefore be corrected.

5.2. Method of instrumentation

The complete system is shown diagrammatically in

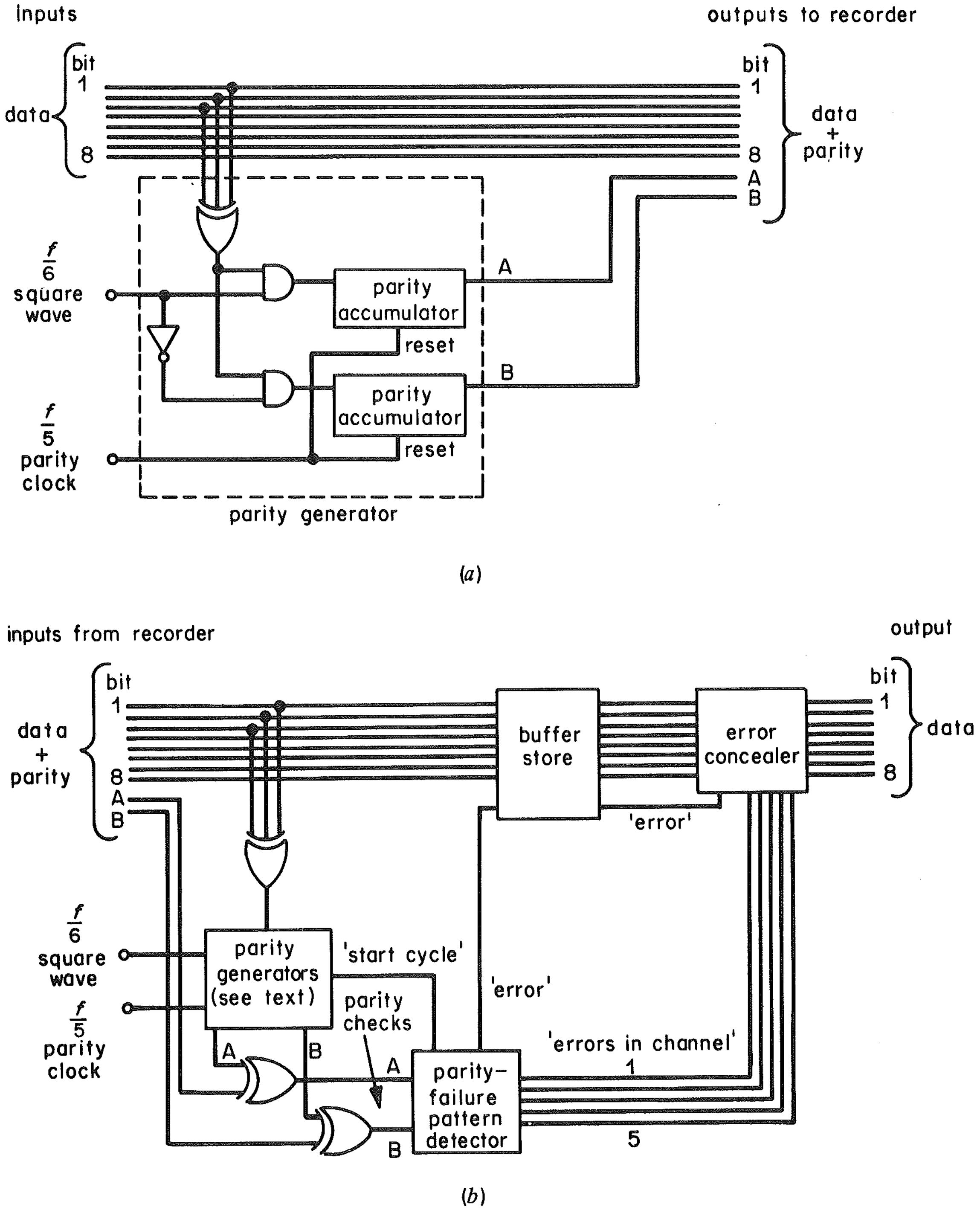


Fig. 2 - System 1
(*a*) input equipment (*b*) output equipment

Fig. 4. On replay, the only information that is not directly available is whether A and B are allocated to bits 1 and 2 or to bits 4 and 3; as only two possibilities exist, the correct one is readily established by regenerating parity in both ways and comparing each with that replayed from tape.

If parity bit A or B has indicated that an error burst is affecting one or the 4 most significant bits of some words, the appropriate bit is inverted in those words which are confirmed by W to contain an error. Errors detected by W only are concealed by word substitution.

As stated previously, an error burst may include one or more relatively long periods without effective errors. During such periods the equipment must remember the location of the error burst, so that correction may be resumed when the errors reappear. However, when two unrelated error burst occur successively, the equipment must distinguish between them, otherwise 'correction' may be mistakenly applied. Experiment has shown that error bursts separated by more than about 100 µs are in general unrelated, whereas related bursts are usually separated by a much shorter time interval; the equipment makes use of this property in deciding when an error burst has ended.

6. Results

The characteristics of the digital recorder are such that a large tape dropout affects about 4 lines of the television field in which it occurs; at an average error rate of 10^{-5} the disturbance caused by dropouts in recorded pictures is therefore considerable.

The installation of System 1 was found to reduce the effective incidence of severe picture impairment by a factor of about 10; this results in pictures which, although viewable, are not of broadcast quality.

The System 2 equipment was provided with a switch which suppressed the correction facility so that all errors detected by parity bit W were concealed. Using concealment only, the results were much better than those obtained with System 1; visible disturbances to the picture occurred much less often. When the correction system was switched on, a further improvement was observable, particularly in the region of vertical edges where the shortcomings of the concealment method were most readily perceived. The slight residual impairment was due to the concealment of errors which occurred singly or in bursts too short to be corrected, and to errors in the 3 least significant data bits which fall outside the scope of the protection system.

7. Conclusions

Two error protection systems have been designed for use with the experimental digital video tape recorder. It has been demonstrated that by taking advantage of the properties both of the recorded data and of the recorder itself, a considerable degree of error protection may be obtained by the allocation of quite small proportions of the total recorded data to parity bits.

System 1, in which 4·8% of the data comprises parity bits, effects a considerable subjective improvement over unprotected pictures, although the degree of protection is insufficient for broadcast purposes.

In System 2 the proportion of parity bits is 16·7%; the residual disturbance is very small, and picture quality is very comparable with that from a conventional video tape recorder.

To maintain high picture quality in multiple-generation recordings a greater proportion of parity bits would be required, because of the cumulative effect both of error concealment and of errors in the unprotected bits of lesser significance.

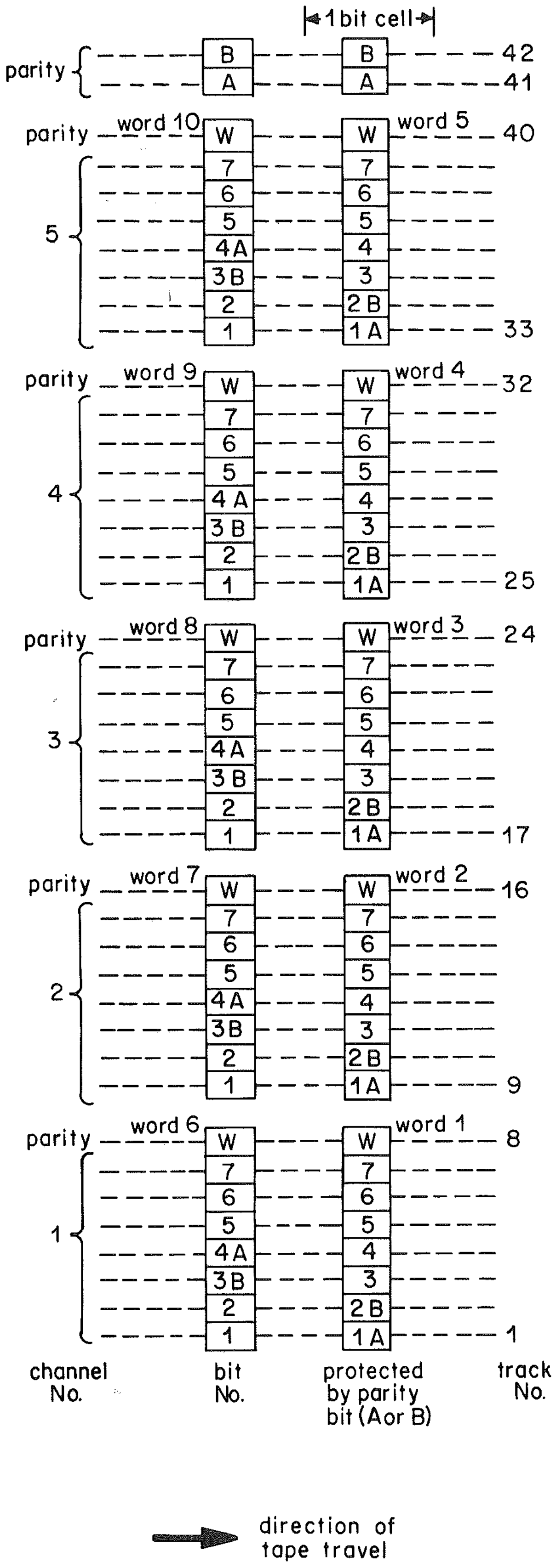
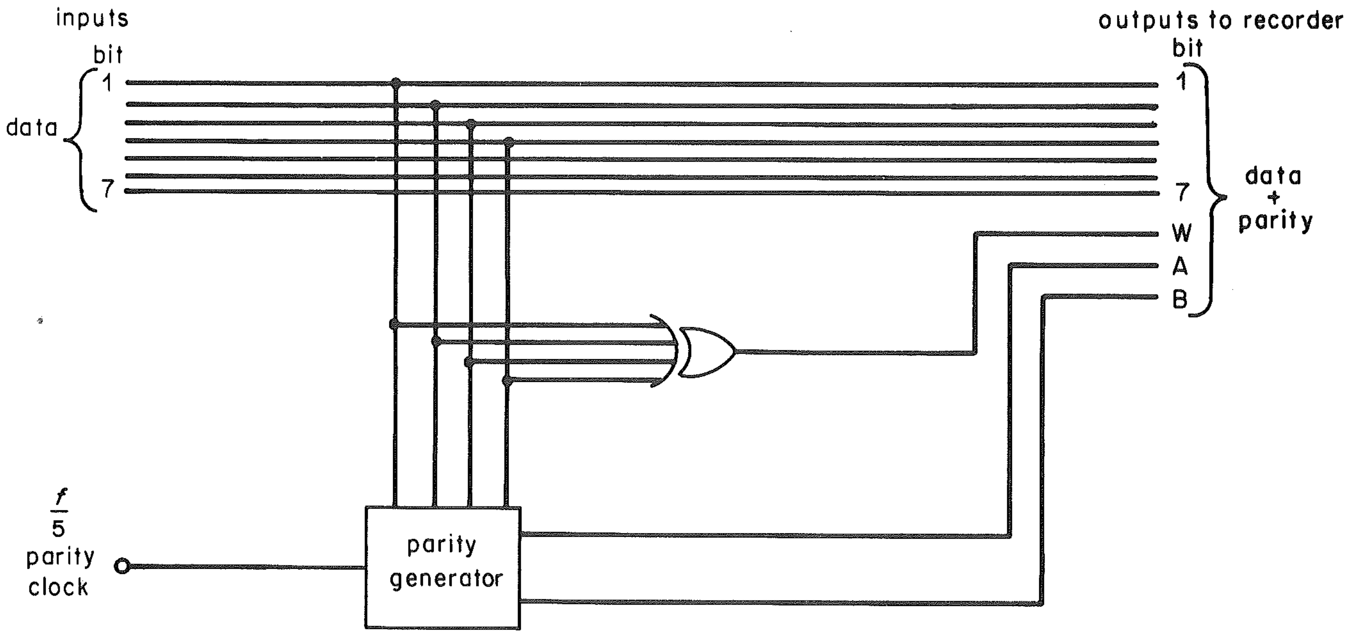
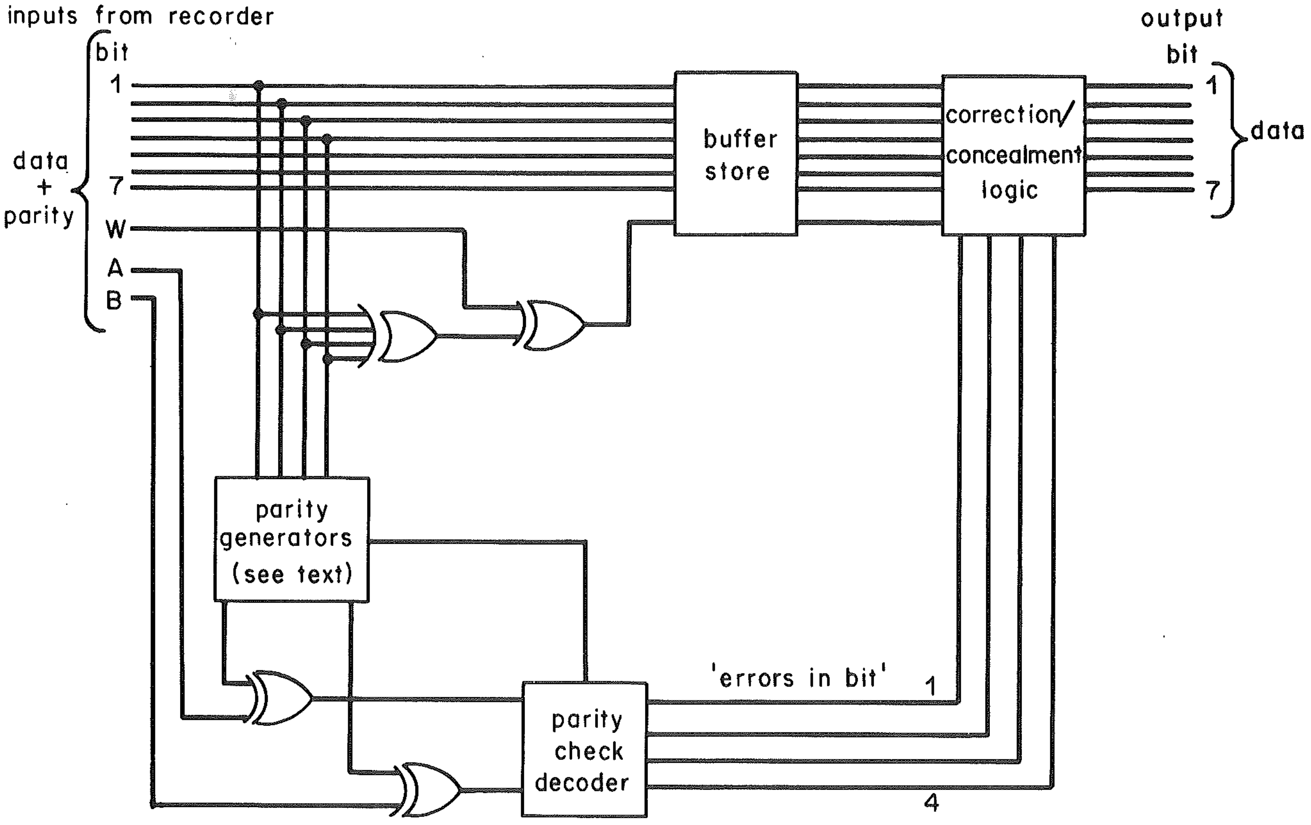


Fig. 3 - System 2: parity allocation scheme



(*a*)



(*b*)

Fig. 4 - System 2
(*a*) input equipment (*b*) output equipment

8. References

1. BELLIS, F.A. An experimental digital television recorder. BBC Research Department Report in course of preparation.
2. DEVEREUX, V.G. *and* MEARES, D.J. Pulse code modulation of video signals: subjective effect of random digit errors. BBC Research Department Report No. 1972/14.

SMW/VK

Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP